PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01J 37/30, 37/317

A1

(11) International Publication Number: WO 98/48443

(43) International Publication Date: 29 October 1998 (29.10.98)

(21) International Application Number: PCT/US98/06748

(22) International Filing Date: 6 April 1998 (06.04.98)

(30) Priority Data:
08/844,210 18 April 1997 (18.04.97) US

(71) Applicant: ETEC SYSTEMS, INC. [US/US]; 26460 Corporate Avenue, Hayward, CA 94545 (US).

(72) Inventor: WIESNER, John, C.; 16978 Hinton Street, Castro Valley, CA 94546 (US).

(74) Agent: KLIVANS, Norman, R.; Skjerven, Morrill, MacPherson, Franklin & Friel, LLPP, Suite 700, 25 Metro Drive, San Jose, CA 95110 (US).

(81) Designated States: CA, JP, KR, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: MULTI-BEAM ARRAY ELECTRON OPTICS

(57) Abstract

A multi-beam array optics system useful as a pattern generator for electron beam lithography includes a field emitter array of micro-cathodes formed on a substrate for emitting an electron multi-beam array, an extracting electrode array on the substrate for controlling the emission of the field emitter array, a deflecting array on the substrate for deflecting the individual electron beams emitted by the micro-cathode to reduce beam shift, and electron optical elements that accelerate and direct the multi-beam array to a target as if it were a single unitary beam.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

MULTI-BEAM ARRAY ELECTRON OPTICS

FIELD OF THE INVENTION

This invention relates to multi-beam array charged particle optics and related systems, and particularly to a pattern generator using a multi-beam array.

BACKGROUND

It is well known in the field of electron beam pattern generation that it is desirable to increase the throughput of pattern generation systems. The two main applications for such pattern generation systems are making masks for use in semiconductor fabrication by photolithography and direct writing of patterns onto wafers to form semiconductor devices. The need to individually scan an electron beam or ion beam pattern onto a substrate, i.e. a mask or a wafer, is a relatively slow process. One attempt to improve the throughput in for instance electron beam pattern generators is described in "A Concept for a 10 GHz Pixel Rate (Multiple) E-Beam Machine" by D.J.G.M. Roelofs et al., Microcircuit Engineering 83, 1983, pp. 91 and following, which discloses use of a matrix of 32x32 focused electron beamlets which can be blanked individually. Each beamlet is individually focussed by a so-called fly's eye lens which is a composite composed of a number of small lenses, each small lens being associated with one of the beamlets.

This approach is deficient at least because each individual beamlet is susceptible to asymmetries of various kinds due to contamination present in the electron beam column, for instance due to particles lodged in apertures in the column. This contamination operates differentially on the various beamlets, resulting in the beamlets being displaced relative to one another, reducing the accuracy of the pattern being

written.

Also known is the microcolumn approach in which individual microcolumns, each for instance one centimeter in diameter, are arranged in a square array to provide a multiplicity of electron beams. This is complex and expensive due to the need to individually fabricate the microcolumns, each having its own deflector, accelerator, and focussing electron beam optics.

Further known is the array cathode approach, which achieves high density integration of electron beam sources in one and two dimensions. Due to dielectric breakdown, these devices are limited in the energy that may be imparted to the emerging electrons, and thus have limited utility for electron beam pattern generation.

Also known in the art is the use of negative electron affinity photocathodes illuminated by laser beam as multibeam sources of electrons. Schneider et al., J. Vac. Sci. Technol. B 14(6), 3782-3766, Nov/Dec 1996 propose such an electron beam system. Negative electron affinity materials such as cesiated GaAs are known to be extremely sensitive to contamination, which reduces or eliminates the emission of electrons. In the vacuum environment typically found in an electron beam pattern generator, one therefore expects limited lifetime for such a multibeam cathode.

Prior work in this field does not solve the problem of increasing throughput of charged particle beam systems while being commercially feasible. The main obstacles to commercialization of direct writing of semiconductor wafers are on the one hand the low throughput of conventional charged particle beam systems, and on the other hand the very limited beam energy, on the order of a few hundred volts, of parallel array beam sources. (See, for example,

MacDonald et al., Proceedings SPIE 2522 (1995) 220-229.) This limited beam energy forces the optical path length from emitter to target to be very short (approx. 1 mm) in order that there not be undue inter-beamlet distortions. Further, because of the low energy, the particles cannot penetrate conventionally thick resist materials (4000 Å) on the target. For this reason the resist is not exposed. Furthermore, alignment marks buried under such resist are not visible to the beams.

Hence to date commercial use of electron beam lithography has been limited to mask making. Even for mask making it is desirable to increase throughput using beams of conventional energy, as integrated circuits become more complex, requiring more complex masks.

SUMMARY

In accordance with this invention, a pattern generator and a method of generating patterns use a source of charged particles, the source being an array of individual source elements, formed in one embodiment on a single substrate, and each source element in the source emitting an individual charged particle beam. The charged particle beams then pass through a beam assemblage optics which receives the individual charged particle beams and controls and accelerates them as if they were a single beam. That is to say, in the beam assemblage optics there is no individual deflector or accelerator for each beam. Instead, the individual charged particle beams are treated as a single unitary beam, and then are accelerated and directed onto a target, for instance a semiconductor wafer or a reticle substrate held on a suitable support, as in conventional charged particle beam lithography.

Typically the beam assemblage optics includes at least one deflector which deflects substantially

uniformly the entire beam assemblage, a focus element which is a conventional "lens", and an accelerator element which accelerates the entire beam assemblage as if it were a single beam, i.e. does not independently accelerate the individual beams but accelerates all the beams uniformly. This pattern generator may operate in either a vector scan or raster scan mode.

Each individual element in the source is individually addressable in terms of being blanked and unblanked. In some embodiments instead of the individual source elements being blanked and unblanked, a group of elements (for instance a square subarray of source elements) is blanked and unblanked. The blanking and unblanking typically are accomplished by an individual source potential provided to each source element or by an individual extraction potential provided to each source element.

"Beam" here refers to an identifiable stream of charged particles. In accordance with common usage this disclosure uses the term "beam" independently of whether the beam itself is blanked (turned off) or turned on. Thus this defines a static beam axis which is the central path followed by the particles in the beam. "Beamlet" here refers specifically to an individual beam within the assemblage of beams in a multi-beam system.

Multi-beam here refers to multiple charged particle beams in a single grouping of beams. ("Multi-beam" as used here is not intended to refer here to a multi-column electron beam system as known in the art, where individual electron beams are each in its own column and each has its own optical arrangement.) The term "array" used herein refers to for instance (but is not limited to) a row and column array having whatever shape is desired i.e. square, rectangular, circular, or linear, disposed in one or two dimensions. Other array

geometries may be appropriate. The array need not lie in a plane but may be on some other regular surface such as the surface of a sphere or cylinder. The array of individual particle source elements is provided with extractors for extracting the particles from the source elements, thereby initiating the formation of a multiplicity of individual electron beams. This extraction can either be by a structure integrated with the array source itself as an array of individual extractors, or be a single extractor for all of the particle sources as a collective.

The array of source elements is provided with blanking and unblanking (turning off and turning on) structure which in one embodiment operates on each source element independently of each other source element. Alternatively the independence is not of individual source elements in some embodiments, but is an arbitrary collection or grouping of source elements, i.e. a subarray. For instance it may be desirable in a rectangular array to turn on or off an entire selected row or column of source elements independently of the other rows or columns, or to turn off small rectangular blocks of source elements. The blanking may be provided by independent control of the individual source element potential (voltages) or via the individual extraction potentials where individual extractors are provided, or a combination thereof.

In another embodiment, the source array includes not only an independent blanking structure but also independent "lenses" (one for each source element) for focussing the particle beams. ("Lens" and "optics" or "optical" here conventionally refer not to light optics or light refractive lenses but to electro-magnetic or electrostatic structures for focusing charged particle beams.) These lenses are fabricated as additional steps in the fabrication of the source structure. The

lenses are used for specific particle beam system applications, for example to match the source optics to the column optics for efficient beam transport. In one embodiment, independent deflectors are provided for the individual beams. Again these individual deflectors are fabricated as additional steps in the source structure fabrication process and are integrated therein. A selected beam deflector, when actuated, causes the direction of the particular electron beam emitted from the associated source element to be changed from one direction generally aligned with the particle beam system axis to a slightly different direction; typically the deflection is only within a few degrees of the overall beam axis but is greater in other embodiments.

The source array contemplated within the scope of this invention emits particles which are electrons or ions. In one embodiment using electrons as the charged particles, the particle source is called a cathode or cathode array, emphasizing the multiplicity of independent cathodes. This source array is typically fabricated as an integrated structure. There is a substantial literature on such integrated cathode arrays, and several suitable emission techniques and structures are known in the art including field emission, negative electron affinity and thermionic cathodes arranged as arrays of emitters.

Processes for fabricating submicron electron emitter arrays are described in U.S. Pat. No. 5,199,197 MacDonald et al., issued April 6, 1993 and in U.S. Pat. No. 5,126,287 Jones, issued June 30, 1992, both incorporated herein by reference. The advantages of an integrated two-dimensional array of emitter structures are described in U.S. Pat. No. 5,363,021 MacDonald, issued Nov. 8, 1994, also incorporated herein by reference. Processes for fabricating ion emitter

arrays are described in U.S. Patent No. 4.902,898 issued February 20, 1990 to Jones et al., incorporated herein by reference.

Thus in accordance with the present invention, a multi-beam optics system includes a multi-beam generator which generates an assemblage of electron beams, and beam assemblage electron optics for both accelerating and directing the beam assemblage, as if it were a single unitary beam, to a target, e.g. a semiconductor wafer or reticle substrate. The multi-beam generator includes an emitter array (an array of field emitter cathodes), and an emission control array for controlling the magnitude of the emission current, both formed on a single (e.g. silicon) substrate. In one embodiment the control array is an integrated extractor/blanker electrode array following the field emitters (i.e., sequential in space along the emitted electron beams). The multi-beam generator in one embodiment includes an electro-static deflector array for deflecting the individual beams by an appropriate amount, and in some embodiments a following lens array also integrated on the same substrate.

The beam assemblage optics take into account the necessity of transporting relatively high levels of total beam current in a short total beam path length, thereby post-accelerating the beam assemblage to a desired final beam energy. The final beam energy is chosen to reduce inter-beamlet interactions thereby permitting a lengthening of the space between the emitting array and the target. With the increased length it becomes possible to utilize conventional electron optics for focusing and deflection. The beam energy is also chosen to penetrate resist materials of conventional thickness in order both to expose the resist and to develop backscatter signals for determining the location of alignment marks which may

lie beneath the resist. Also taken into account in the configuration of the elements of the beam assemblage optics is that the multi-beam source (cathode array) is extensive in its transverse dimensions as opposed to the conventional quasi-point source, as well as other features of the beam assemblage such as the varying beam current at the target. Faithful electron optics projection of transversely extensive sources as used in accordance with this invention has been faced in electron beam projection lithography; see M.B. Heritage, J. Vac. Sci. Technol., 12 6 (Nov/Dec 1975) pp. 1135-1140 and B. Lischke et al., Optik 54 (1979) (4) pp. 325-341, both incorporated herein by reference.

Also known in the art are other lens and deflection designs suitable for use in accordance with this invention and including Moving Objective Lens, J. Vac. Sci. Technol. 15(3) (May/June 1978) 849-52; Variable Axis Lens, J. Vac. Sci. Technol. 19(4) (Nov./Dec. 1981) 1058-63; Variable Axis Immersion Lens, Microcircuit Engineering 83 (1983) 106-16; J. Vac. Sci. Technol. B6(6) (Nov./Dec. 1988) 1995-8; J. Vac. Sci. Technol. B88(6) (Nov./Dec. 1990); 1682-5.

The above and other objects, features and advantages of the present invention will become apparent from the following detailed description of the invention in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagram of a multi-beam optics system in accordance with the present invention.

Figure 2 is a partial cross-sectional view of a multi-beam field emission source in accordance with the present invention.

Figure 3A shows a tip-type cathode, and Figure 3B shows a strip cathode, for use in the source of Figure 2.

Figure 4 is a diagram of a beam assemblage optics in accordance with the present invention.

Figure 4B is a more detailed diagram of beam assemblage optics.

DETAILED DESCRIPTION

The present multi-beam pattern generator includes a source which is an array of charged particle source elements. An integrated extractor/blanker electrode control array follows these charged particle sources ("following" here means sequential in space along the axis of the emitted charged particle beam or "downstream"), followed in one embodiment by an array of electric deflectors to provide individual beam deflection transverse to the beam path, and followed in one embodiment by a lens array. The source array structure is further integrated with electrical connections to suitable control electronics, which provides control signals and controls acceleration voltage, and which may be partially integrated with the emitter array itself. The lens array is needed only for certain embodiments, for example if the emission pattern from the source element is not well matched in its spatial and velocity distributions to the acceptance of the downstream beam assemblage optics.

The source array without the array of deflectors can be used as a "dot matrix" pattern generator, with applications to lithography as in U.S. Patent 4,153,843, incorporated by reference.

Hence the multi-beam generator in one embodiment includes in the source an array of electron field emitters (or a Schottky-assisted cathode emitter array) with fabricated micro-blankers and micro-deflectors and an electron optical lens (of conventional design) to form an array image on a target substrate. Use of field emitters as cathode elements permits essentially

cathode imaging (without other elements). Prior multi-beam optics requires optical elements downstream of the cathode, which undesirably leads to differential beam drift and other effects. The present multi-beam generator forms and treats the individual beams only at the beam source, which is configured to minimize beam drift and other effects. Thereafter, the downstream beam assemblage optics affects the beams as if they were unitary, i.e. as if they were one beam; hence no source of differential effects exists beyond the multi-beam source itself.

Figure 1 is a diagram of a multi-beam pattern generator system 1 contained in a conventional vacuum chamber (not shown) and which includes a multi-beam electron source 2 (hereafter referred to as the multi-beam source) which generates an assemblage of electron beams 6, and beam assemblage optics 4 to direct the assemblage of beams 6 to a target, e.g. a workpiece or wafer 3 held on a conventional X-Y movable stage (precision motion table) 5. Conventional backscattered electron detector 7 provides for detection of electrons scattered back from the target 3.

The multi-beam source 2, only a small part of which is shown in cross section in detail in Figure 2, includes an electron field emitter array of micro-cathodes 202 arranged in e.g. a rectangular array (in a plan view not shown), and extracting electrode array 203. Both micro-cathode array 202 and extracting electrode array 203 are formed on a silicon (or other suitable material) substrate 201. Cathodes 202 are brought to a reference potential V_R by an applied voltage. Extracting electrodes 203 are brought to a positive extraction potential V_E with respect to the reference potential V_R by a second applied voltage. Extracting electrodes 203 each define a hole for the passage of electrons emitted by cathodes 201. Multi-

beam source 2 in one embodiment includes an anode array 204 which is an accelerator and is brought to a positive potential V_A with respect to the extraction potential V_E and defining holes for the passage of the electron beams as well.

In one embodiment, deflector arrays including a x-deflector array 205 and a y-deflector array 206 with associated integrated control electronics 230 are integrated with and located downstream (e.g. 0.1 to 10 μm) from anode array 204 with respect to the direction of propagation of the individual emitted beams, to deflect the individual beams transversely to the beam path by appropriately scaled amounts, depending on system design factors.

Extracting electrodes 203, anode 204 and, x, y deflector electrodes 205, 206 are formed of a succession of insulating and conductive layers formed by conventional IC fabrication techniques on substrate 201 as shown in Figure 2. The insulating layers 207, 208, 209 are e.g. silicon dioxide or other dielectric materials known in the IC fabrication art. The conductive layers 203, 204, 205 and 206 are e.g. conventionally deposited and patterned aluminum or its alloys; other conductive materials such as polysilicon, Ti-Pd-Au, Ti-Pt-Au and Ti-W may be used.

Further detail of the structure and fabrication of the source is not provided herein since suitable sources are known in the art. See e.g. Epstein et al. U.S. Patent No. 5,070,282; "Dot Matrix Electron Beam Lithography" by Newman et al., J. Vac. Sci. Technology, 131(4) Oct.-Dec. 1983, pp. 993 and following, and "Addressable Array Cathodes for Projection Electron Beam Lithography", MacDonald et al., SRC Workshop, Dallas, Texas, 1991, p. 241 and following, all incorporated herein by reference, for detail of the structure and fabrication of the source.

In the structure of Figure 2, it is desirable to provide emission stability in terms of the amount of output current and current variations between various emitters. Also it is desirable to extend the lifetime of the emitters to prevent burnout. It is within the scope of the invention therefore to provide emitter redundancy. In one embodiment, the emitters are associated in groups, each group including at least one redundant emitter element; each actual beam is then the sum of emissions from all the emitters in the group. Thus if one emitter burns out, a redundant emitter can be substituted therefor while maintaining a level output current.

Since each individual electron source (emitter or cathode element) is individually controlled both in terms of blanking and unblanking and deflection, each defines an individual beamlet and so can be used to create a fine grain pattern. Thus in one embodiment the current level to the individual emitters is controlled to provide a grey scale (variable intensity) effect, for instance by pulse modulation. Since the individual emitters may be controlled, pattern generator in accordance with this invention is a high speed parallel structure permitting very high throughput for pattern imaging.

Micro-cathodes 202 may be e.g. tip-type cathodes or strips as illustrated, respectively, in Figures 3A and 3B and known in the art. Also, other cathode types such as circular wedges are usable. The strip type cathode is described in Spallas and MacDonald in IEDM Technical Digest, 1991, referred to below.

In Figure 3A depicting a tip-type cathode, a TiW extraction electrode 303 surrounds a silicon electrode tip 301. In Figure 3B depicting a strip-type, a silicon base 310 defines a lower silicon strip 312, surrounded by parallel TiW extraction electrodes 324.

Tip-type cathodes are the most common type of micro-cathodes described in the art; strips and circular wedges have larger emitting area than the tip-type and produce larger total currents.

Micro-cathodes 202 are formed using a known lateral high temperature thermal oxidation process. Micro-cathodes so formed are inherently uniform in height, profile and radii of curvature, and the extraction electrodes are self-aligned. Cathodes with very sharp tips and with very small tip-to-extraction electrode distance allow low operational voltage operation while producing very large, stable average current densities. The process sequence for fabrication of such micro-cathodes is based on the process sequence developed for fabrication of silicon-on-insulator (SOI) islands. Spallas and MacDonald in "Fabrication and Operation of Silicon Field Emission Cathode Arrays", IEDM Technical Digest, Washington, D.C. 1991, pp. 209 and disclose the details of this fabrication process, and is incorporated herein by reference.

A control electrode array (not shown) may be provided between extracting electrode array 203 and anode array 204, and brought to a negative control potential V_c with respect to the extracting electrodes in order to reduce the emission current to a fraction of the uncontrolled emission current. For certain pattern generation applications, as described above, a lens array (not shown) is integrated into multi-beam source 2 downstream of the deflector arrays 205, 206 along the direction of the beams. See U.S. Patent 5,126,287 and N.C. MacDonald et al., Proceedings SPIE 2522 (July 1995) pp. 220-229 for such integration, both incorporated by reference. The source structure 2 is further provided with electrical connections (not shown as being outside the plane of the drawing) to

conventional control electronics 220. Control electronics 220 provide control signals and control acceleration voltage for multi-beam source 2 and in one embodiment is circuitry formed e.g. by conventional integrated circuit fabrication techniques and which is at least partially integrated on substrate 201.

Beam assemblage 6, generated by multi-beam source 2, then passes through beam assemblage optics 4. Figure 4A shows generally beam assemblage optics 4 in cross section. Beam assemblage optics 4 transports beam assemblage 6 as a unit (i.e., as if it were one beam) from the source 2 to target 3 in a preferably short beam path to minimize beam interactions. The beam assemblage optics 6 includes in one embodiment a conventional charged particle beam accelerator 401 to post-accelerate beam assemblage 6 to a desired final beam energy, a conventional focusing system (lens) 402 to focus (or defocus) beam assemblage 6, and a conventional X-Y deflector 404 to deflect beam assemblage 6 to a specified location of the target 403. Beam assemblage optics 4 is conventional as used in electron beam pattern generators, taking into account design factors, such as that the present electron source 2 is extensive in its transverse dimension as opposed to the conventional quasi-point electron source, and that a short total beam path length is desirable, and accounting for other aspects of the beam assemblage, such as the varying beam current. Since the beam assemblage optics 4 treats the beams as if they are one beam, no cause for differential effects thereby exists downstream of the source 2.

Figure 4B shows additional detail to better explain the structure of Figure 4A. Particle source 2 generates electron beams which pass through an opening in accelerator electrode 401, at a positive potential with respect to the cathode array in source 2. A

limiting aperture 412 is provided. Deflection coils 404 are next, followed by a projection lens 402. (Note here the deflection and focusing lens structures are in different order than in Fig. 4A). The target is not shown in Fig. 4B.

The multi-beam generator in another embodiment includes in the source an array of ion emitters with fabricated micro-blankers and micro-deflectors and an accelerating ion optical lens (of conventional design) to form an array image on a target substrate. A suitable ion source is known in the art; see e.g. Jones et al., U.S. Patent No. 4,902,898, incorporated herein by reference. (See especially Figs. 8, 9, 10.) Suitable accelerating ion optical lens structures are known in the art; see e.g. Stengl et al., U.S. Patent No. 4,985,634, incorporated herein by reference.

The present invention is suitable for applications including lithography, inspection, and microscopy wherein charged particle beams having high resolution, high average current and beam control are required.

Although the present invention has been described and illustrated with particular embodiments it will be clearly understood that this is by way of illustration and example only and is not to be taken by way of limitation. The spirit and scope of the present invention is limited only by the appended claims.

CLAIMS

We claim:

1. A pattern generator comprising:

a source of electrons, the source including an array of individual field emission elements each generating an individual electron beam;

a beam assemblage optics located to receive the individual electron beams and to accelerate and control the individual electron beams as an assemblage; and

a target location onto which the beam assemblage optics directs the assemblage of beams.

2. The pattern generator of Claim 1, wherein the array of individual emission elements is a two dimensional array.

3. The pattern generator of Claim 1, wherein each emission element is independently blanked and unblanked.

4. The pattern generator of Claim 1, wherein the source of electrons blanks and unblanks groups of the emission elements.

5. The pattern generator of Claim 1, wherein each emission element is provided with a source potential, and the source potential of each emission element is independently controlled.

6. The pattern generator of Claim 1, wherein each emission element is provided with an extraction potential, and the extraction potential of each emission element is independently controlled.

7. The pattern generator of Claim 1, further

comprising, associated with each emission element, an individual deflection element for deflecting electrons emitted from that emission element.

8. The pattern generator of Claim 1, further comprising a deflector array integrated with the source of electrons, for deflecting individual electron beams.

9. The pattern generator of Claim 8, wherein the deflector array includes first and second deflectors associated with each individual emission element, for deflecting the electron beam from that emission element in two orthogonal directions.

10. The pattern generator of Claim 1, further comprising an accelerator array integrated with the source of electrons, for individually accelerating the electron beams.

11. The pattern generator of Claim 1, wherein the beam assemblage optics includes a deflector that deflects the entire assemblage of individual electron beams.

12. The pattern generator of Claim 7, wherein the deflector deflects each electron beam substantially identically.

13. The pattern generator of Claim 1, wherein the beam assemblage optics includes a focus element that focusses the entire assemblage of individual electron beams.

14. The pattern generator of Claim 1, wherein the beam assemblage optics accelerates the individual electron beams by an accelerator element.

15. The pattern generator of Claim 1, wherein the pattern generator forms a pattern on the workpiece by a vector scan.

16. The pattern generator of Claim 1, wherein the pattern generator forms a pattern on the workpiece by a raster scan.

17. The pattern generator of Claim 1, wherein the target location is a support for a substrate.

18. A method for providing a multi-beam assemblage comprising the steps of:

providing a field emission source of electrons arranged to generate a multi-beam in an array;

manipulating individual electron beams generated in the array at a close proximity to the source; and

then, directing and accelerating the manipulated multi-beam to a target as if the multi-beam was a single electron beam.

19. The method of Claim 18, wherein the manipulating step includes extracting individual electron beams.

20. The method of Claim 18, wherein the manipulating step includes independently accelerating the individual electron beams.

21. The method of Claim 18, wherein the manipulating step includes independently deflecting the individual electron beams transversely to a direction of propagation of the individual electron beams.

22. The method of Claim 18, wherein the accelerating step includes accelerating the multi-beam

to a predetermined final energy.

23. The method of Claim 18, wherein the directing step includes focussing the multi-beam onto the target.

24. The method of Claim 18, wherein the directing step includes deflecting the multi-beam to a specified location on the target.

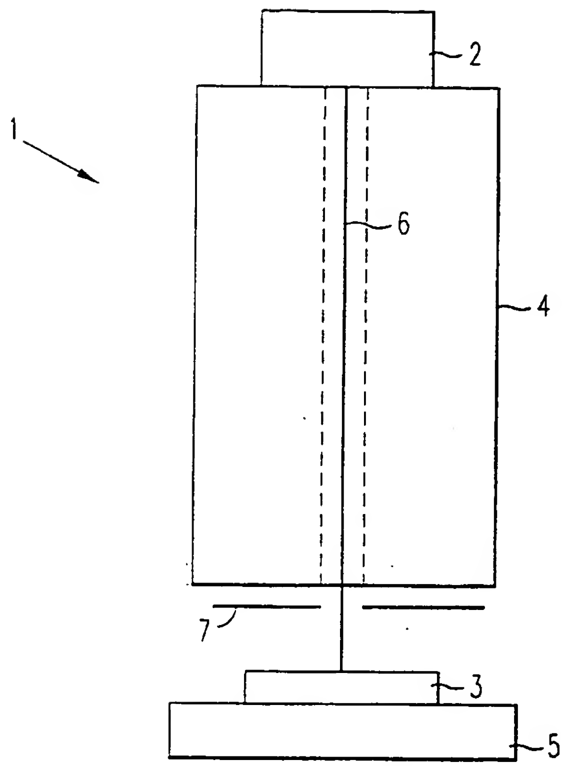

FIG. 1

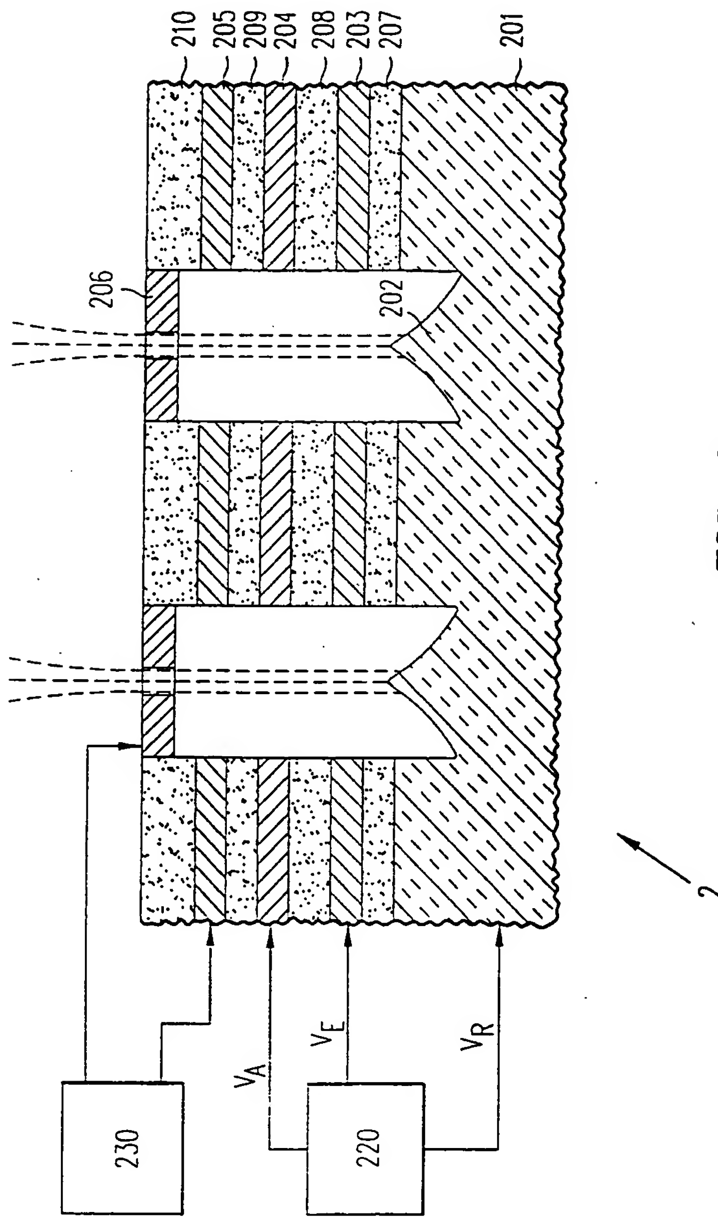

FIG. 2

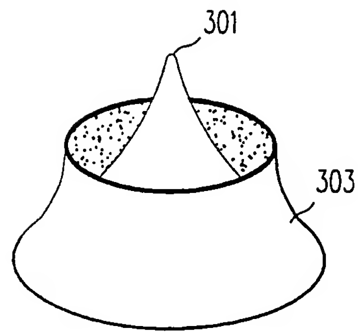

FIG. 3A

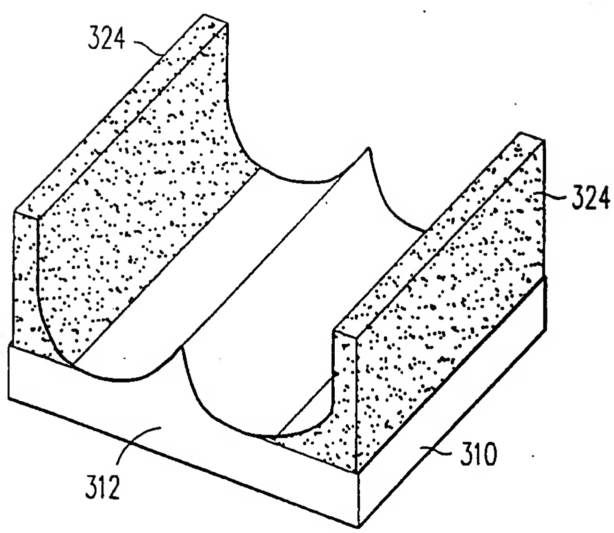

FIG. 3B

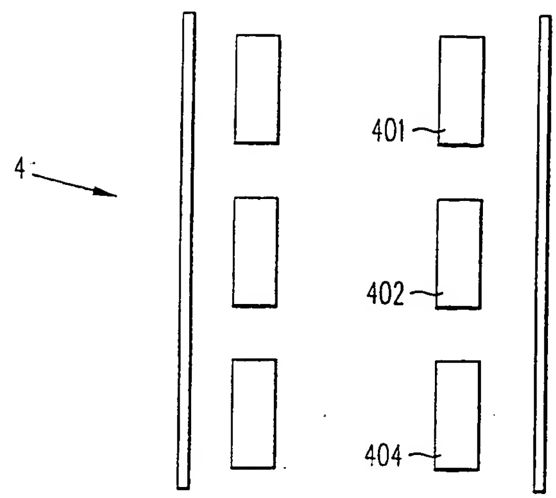

FIG. 4A

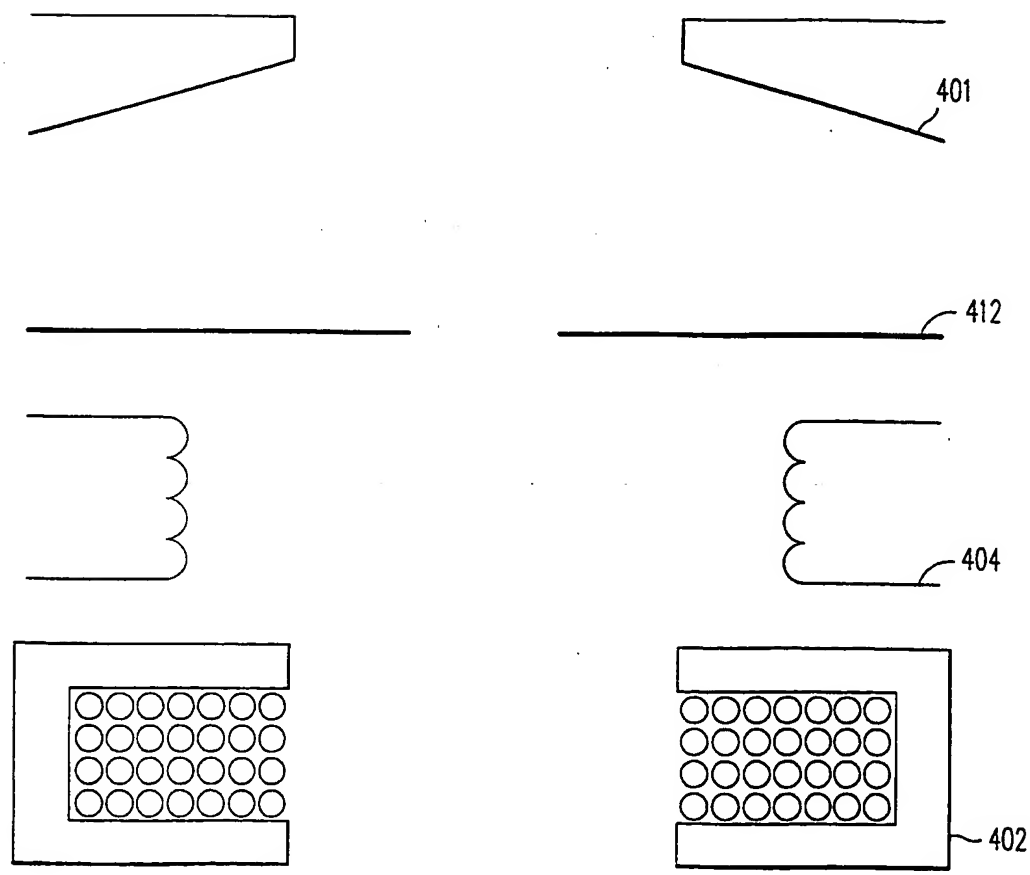

FIG. 4B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/06748

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01J37/30 H01J37/317

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 095, no. 010, 30 November 1995 & JP 07 192682 A (AGENCY OF IND SCIENCE & TECHNOL), 28 July 1995 see abstract; figures	1,4-6, 10-13, 15,18-23
A	EP 0 605 964 A (AT & T CORP) 13 July 1994 see column 10, line 53 - column 11, line 50; figures 4,5	1,18
A	DE 196 38 109 A (JEOL LTD) 27 March 1997 see abstract; figures	1-3,18
A	EP 0 339 951 A (MICROELECTRONICS CENTER OF NOR) 2 November 1989 cited in the application see abstract; figures	1,18

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 July 1998	05/08/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Schaub, G

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/06748

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 213 664 A (PHILIPS NV) 11 March 1987 see abstract; figures -----	1,18

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

ernational Application No
PCT/US 98/06748

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0605964 A	13-07-1994	US 5395738 A	07-03-1995
		CA 2107451 A	30-06-1994
		JP 6283466 A	07-10-1994
DE 19638109 A	27-03-1997	JP 9153455 A	10-06-1997
		US 5661307 A	26-08-1997
EP 0339951 A	02-11-1989	US 4902898 A	20-02-1990
		JP 2042714 A	13-02-1990
EP 0213664 A	11-03-1987	NL 8502275 A	16-03-1987
		JP 62045110 A	27-02-1987